

# **High-resolution Mapping and Backscatter Studies in Support of the Ripples DRI**

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## **LONG-TERM GOALS**

The long-term goal of the RIPPLES DRI is to develop the ability to predict the geometry and evolution of seafloor morphology and in particular the presence or absence of ripples which have been shown to affect the sub-seafloor penetration of acoustic energy. Specific goals are to:

- 1- Measure and model ripple morphology and gradients on scales ranging up to kilometers
- 2- Understand the response of ripples to changes in wave and wave-current forcing
- 3- Measure and model rates of biological degradation (or production) of seafloor morphology
- 4- Measure and model effects of a distribution of grain-scale properties (e.g. size, density, cohesion) on ripple morphology
- 5- Understand the role of ripples in generating surface and subsurface sedimentary structures.

## **OBJECTIVES**

In support of these long-term goals, the UNH-CCOM team has conducted ultra high-resolution, multi-frequency, multibeam mapping program in order to:

- 1- Establish the overall morphological context in the area of the RIPPLES DRI/SAX04 experiment (bathymetry and acoustic backscatter)
- 2- Establish the detailed distribution of ripples and other small-scale features throughout the experimental area, before the start of the experiment, immediately after deployment of the sensors, and at intervals during the experiment
- 3- Explore techniques for using the backscatter recorded by the multibeam sonar as a means to remotely identify seafloor properties including acoustic parameters, grain-size and biological components.

## **APPROACH**

At the crux of the RIPPLES DRI/SAX04 program is a multi-disciplinary experiment involving the deployment of a number of acoustic sensors in a small area off the coast of Destin, FL. The area selected is the site of the SAX99 experiment, an approximately 1 km<sup>2</sup> area with water depths of

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approximately 18 – 20 m located off the Florida Panhandle (with an extension to deeper water for the DRI program). In support of these efforts, and in order to address our specific objectives, we conducted a series of multibeam sonar surveys of the RIPPLES DRI/SAX04 experiment site that serve multiple purposes. First and foremost, these surveys place the entire experiment in a morphological and lithological context that allows investigators to understand the local bottom relief spectra and sediment distribution over spatial scales ranging from a few kilometers to a few centimeters. At the same time, we provide investigators with the regional (100's to 1000's of meters) distribution of the bathymetry and sediment distribution but with the same level of resolution (10's of centimeters). In addition to addressing questions of ripple morphology and distribution over many scales, we also hope to use the multibeam sonar(s) to determine the acoustic backscatter response of a rippled seafloor over a wide range of angles and under a number of conditions.

The surveys were conducted on a 46' Naval Oceanographic Office (NAVOCEANO) hydrographic survey launch (HSL) that is based in Gulfport, MS and equipped with precision navigation equipment and two state-of-the-art dynamically focused multibeam sonars (a 300 kHz – 130 degree, Simrad EM3002, and a 455 kHz, 120 degree, Reson 8125 – the same sonar we used to resolve ripples and mines off Martha's Vineyard, MA). Both systems collect backscatter as a function of beam angle but in the configurations we are using, only the Simrad system provides a full time series of backscatter values across each beam footprint. The Reson system provides a single average value of backscatter for each beam (thus much lower resolution) or a full time series of backscatter values across the swath with no angular resolution (e.g. standard sidescan sonar). Constraints on the survey were the inability of the NAVOCEANO vessel to work in water shallower than 5 meters and the need for significant overlap of one swath with the next in order to ensure high-resolution. Also, to ensure high quality data and dense data coverage in the along-track direction, survey speeds were kept below 6 knots.

Funding was available for approximately 20 days of survey work through the course of the experiment. We proposed to divide these into 5, 4-day survey blocks so that we may examine both the short and long-term temporal and spatial variations of the ripples with respect to the local environmental conditions. We proposed to spread four of the survey blocks over the time period between early Sept. and mid Nov. and save one of the surveys for an "event response" – a survey conducted directly after a storm event. In planning our survey work we tried to meet the objectives of the RIPPLES DRI, the SAX04 investigators, as well as Naval Research Laboratory (NRL) researchers who are studying coastal processes at an area (known as the TOWER Site) near the RIPPLES DRI/SAX04 experiment and who are contributing to the cost of the field work.

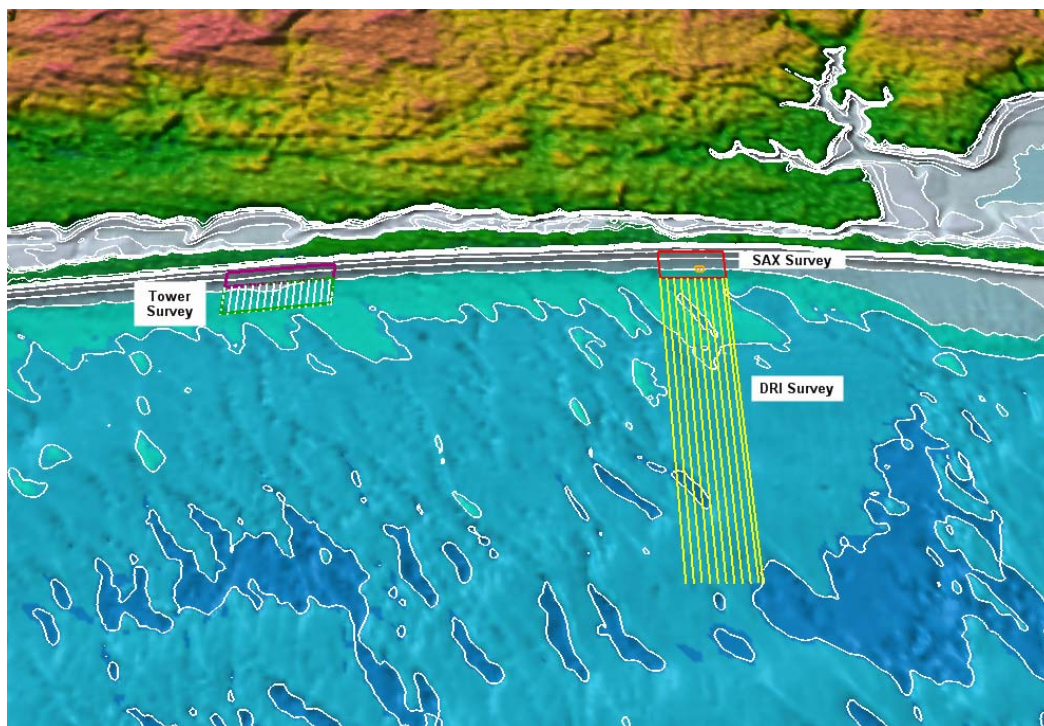
Detailed Survey Plan (Figure 1):

SAX04 Site – an approximately 2 km (EW) by 1 km (NS) box centered around (but slightly offset from) the R/V Seward Johnson anchor site and the buried target site. The survey box starts at approximately the 5 m contour and extends about 1 km offshore from there (to a depth of approximately 18 – 19 m). An area of this size can be fully surveyed with ripple-resolving resolution in approximately one day.

TOWER Site – an approximately 3 km (EW) by 600 m (NS) box directly offshore the coastal meteorology tower. This survey starts at the 5 m contour and continues about 600 m offshore (to approximately the 15 m contour). A full coverage, high-resolution survey in this area takes about one day.

SAX04 Deepwater Lines (DRI Survey) – The RIPPLES DRI objectives call for surveys out to 25 – 30 m depth. It is impossible to get full coverage over an area this large in the time available so the plan called for a series of individual NS lines about 10 km long running from the southern boundary of the SAX04 survey box to approximately 25 – 27 m depth. These lines have a swath width of about 2 times the water depth and thus average about 40 m wide.

TOWER Site Deepwater Lines – NRL requested survey data further offshore but only to 18 m depth.



**Figure 1: Overview of RIPPLES DRI/SAX04 surveys bathymetric map of a region offshore of Destin, FL showing the 1 × 2 km detailed area for the SAX04 survey, the 10 km long, NS Deepwater Lines for the DRI survey, and the 3 km by 600 m detailed TOWER survey area.**

Along with our bathymetric mapping objectives we also hoped to continue our research into the potential role that multibeam sonar backscatter measurements can play in the remote identification of seafloor properties. As described in Fonseca *et al.* (2002), we have been working with the composite roughness model of Jackson *et al.* (1986) to see how it can be applied to the analysis of multibeam sonar data. In Fonseca *et al.* (2002), we modified the model to explore the role of gas in sediments and used this modified model to analyze multibeam sonar data from the Eel River margin. We have continued this work with the development of an interactive tool that is modeled after AVO (Amplitude Versus Offset) analyses that are standardly done in offshore petroleum exploration. The tool automatically ingests multibeam sonar bathymetry and backscatter data, makes all corrections necessary (including corrections for local slope) to calculate true backscatter, and then uses a constrained (by Hamilton physical property inter-relationships) iterative process that adjusts model input parameters (seafloor properties) until they best fit various pre-defined portions of the measured backscatter versus angle of incidence data (Fonseca, Mayer, and Kraft, 2005 – see FY2005 Geoclutter Progress Report).

## WORK COMPLETED

The first of the scheduled surveys (the pre-deployment survey) was conducted between 31 August and 3 September 2004 with both a Reson 8125 and a Simrad EM3002 multibeam echosounder using the NAVOCEANO HSL *Bertram*. The SAX04 Site, the DRI Deepwater Lines (nine), and the TOWER Site were mapped, collecting 120 GB of data in 4 days. Preliminary bathymetric maps were produced within a few days of the survey work and provided to the SAX04 and DRI teams. This initial survey produced the base map from which comparisons to future surveys would be made.

Scheduling of the remaining surveys was hampered considerably due to Hurricane Ivan which made landfall (near Gulf Shores, AL) on 16 September 2004. Hurricane Ivan, although viewed by some as opportunistic for the RIPPLES DRI/SAX04 experiment, caused extensive damage to the Pensacola area. Tentative plans for an “event response” survey to commence on 4 October were completed but were eventually cancelled due to logistical challenges. The US Coast Guard (USCG) Station at Destin, which had agreed to provide docking space for the HSL during the nighttime hours, was damaged and without power. All efforts to secure alternate dock space failed. The second survey was rescheduled to begin in mid-October. Just prior to this date, the HSL encountered serious engine problems and underwent repairs in Panama City.

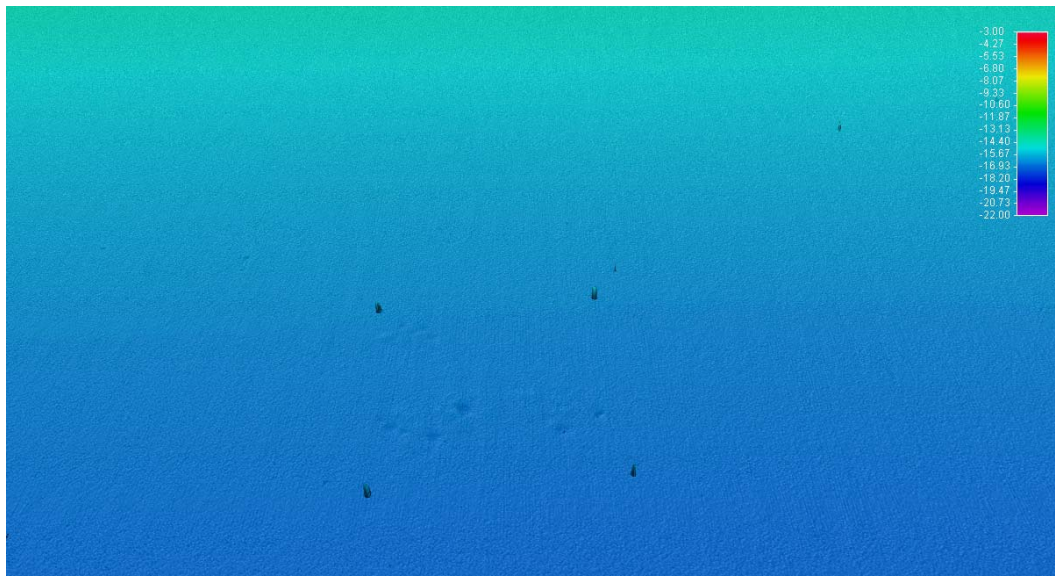
The second survey was eventually conducted between 25-29 October 2004, nearly six weeks post Hurricane Ivan and thus could no longer be considered an “event response” survey. The HSL was permitted to dock at the USCG Station pier which remained without power. A survey plan similar to the first survey was followed with the R/V Seward Johnson remaining moored in the SAX04 site (see Fig. 2) during the survey. A smaller area of the TOWER site, approximately 350 m (NS), was mapped due to the presence of nearly 1.6 meters of fine sand in the northern area of the survey box (see Fig. 4). The Reson 8125 bathymetry data from both surveys and all sites (SAX04, TOWER, and Deepwater Lines) has been processed. The EM3002 data from the SAX04 and TOWER sites has also been processed for acoustic backscatter.

A third survey was scheduled for 13-16 December 2004 but had to be cancelled due to a recurrence of the engine problems on the HSL. To date the HSL is still not available for survey work.

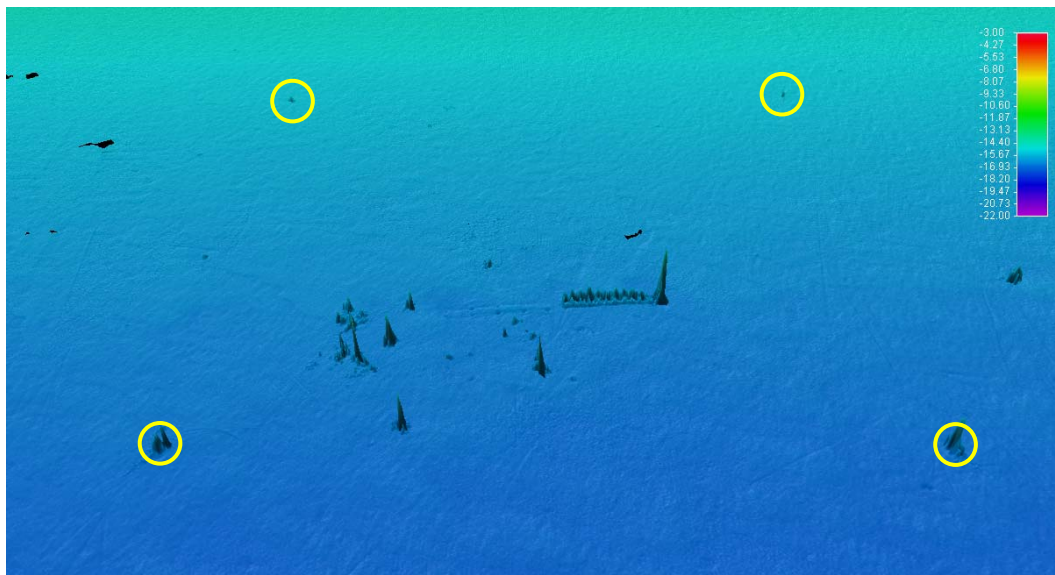
## RESULTS

Shown in Figure 2 is Reson 8125 bathymetry of the SAX04 experiment site from the (a) first and (b) second surveys. The first survey was completed after mine-like targets had been buried in the area bounded by large clump weights (four objects proud on the seafloor). The second survey occurred while the SAX04 experiment was in full-swing. In Figure 2(b), yellow circles outline the location of the R/V Seward Johnson moorings, which remained moored during the multibeam survey. No ripples were observed in the bathymetric data from the first survey, within the vertical resolution of the sonar ( $< 5$  cm). Some small-scale features are present in the bathymetry from the second survey, however most of the ripples generated by Ivan had degraded by the time the survey was completed at the end of October.



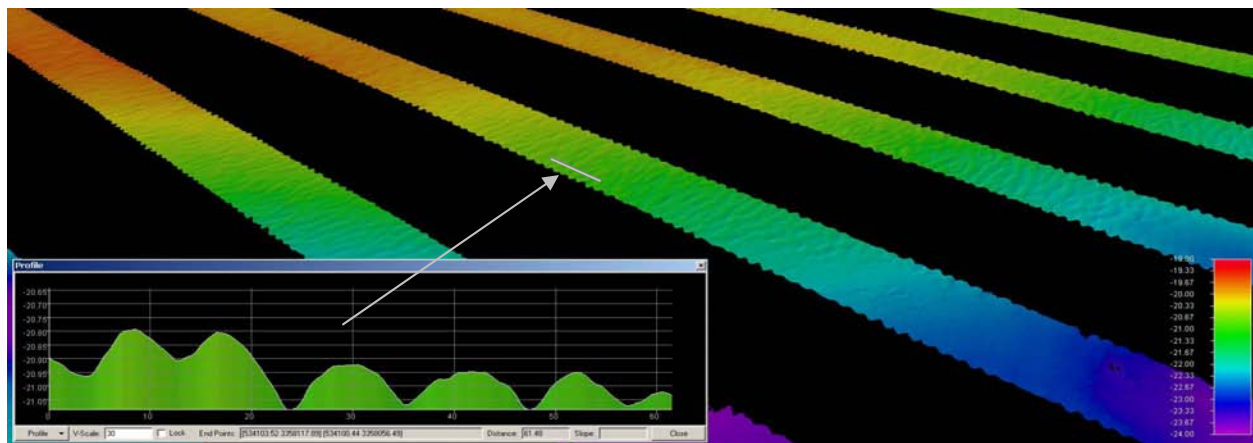


(a)



(b)

**Figure 2: Reson 8125 bathymetry of the SAX04 experiment site during the first (a) and second (b) surveys. In (a), the 2000-lb clump anchors located at each corner of the 60 m by 60 m buried target field are evident. In (b), the yellow circles outline the location of the R/V Seward Johnson moorings. Objects proud on the seafloor are deployed equipment associated with the SAX04 experiment. The large object approximately in the center of the area is the APL-UW rail system (30 m in length). Water depth within the SAX04 site was approximately 17 m.**



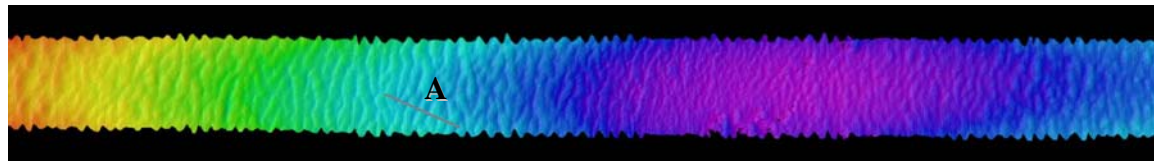
**Figure 3. Perspective view of the deep-water (19-24 m) bathymetry collected with a Reson 8125 multibeam sonar south of the SAX04 survey site (see Fig 1 for location). Bathymetry clearly shows E-W-oriented, long-crested ripples with wavelengths of 8 – 10 m and heights of 10 – 15 cm.**

While little evidence for ripples was found in the buried target field, large-scale ripples are present in the SAX04 Deepwater Lines bathymetric data from the second survey. Shown in Figure 3 is a small section of the NS lines that extend from approximately 19 to 24 m water depth. Long-crested, shore-parallel, ripples are present with wavelengths on the order of 8 to 10 m and amplitudes of 10 to 15 cm.

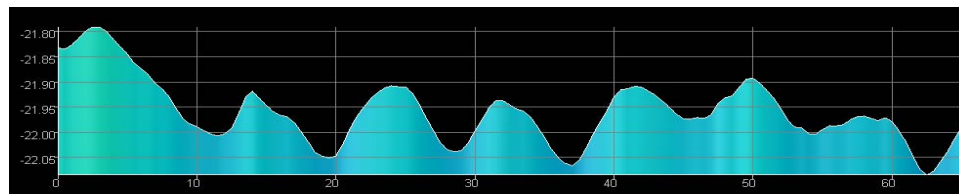
The EM3002 backscatter from the SAX04 site and the NS Deepwater Lines shows primarily uniform, moderate backscatter with a few isolated areas of low backscatter. For example, shown in Figure 4 is a section of one of the NS lines from water depths between 21 and 23 m. The three-dimensional ripples present in the Reson 8125 (see Figure 4(b)) bathymetry are slightly more chaotic than those shown in Figure 3, but still basically shore parallel with wavelengths of approximately 8 m and amplitudes of 10 – 15 cm. The ripple crests are rounded, with a slight asymmetry observed, (the shoreward face is often, though not always, steeper). The Simrad EM3002 acoustic backscatter for the same section of the seabed is shown in Figure 4(c). Low backscatter (fine-grained) sediment is seen to have accumulated in several of the ripple troughs. A bathymetric cross-sectional profile **B**, shown in Figure 4(d), is extracted through the ripples with a low backscatter finer-grained sediment in the troughs. The ripples have about the same wavelength and height as the surrounding ripples but are in a local deep (approximately 23 m). The water depth in this area is approximately 1 m greater than the depth at cross-section **A** where fine-grained sediment has not accumulated in the ripple troughs. The slight increase in water depth could be a contributing factor as to why the finer-grained sediment accumulates or remains in the ripple troughs nearly six weeks following Ivan.

The most visible changes to the seabed following Ivan were observed within the TOWER site (see Fig. 1 for location). Figure 5 shows the Reson 8125 bathymetry from the first (a) and second (b) surveys (before and after Ivan, respectively). A bathymetric difference map (in meters) between the two surveys is shown in (c). Following Ivan (albeit 6 weeks after the storm), the northern (shoreward) region of the survey area shows a net accumulation of sediment of approximately 1.6 m. There is a hinge line at approximately 11 m depth, below which there is an overall deepening of the seafloor to a maximum depth increase of .15 m in the surveyed area. Constrained to the deeper area, and in particular in the vicinity of the 11 m contour, are fingers of fine sand, oriented perpendicular to the shoreline. These shore-perpendicular features, with wavelengths of approximately 10-15 m and

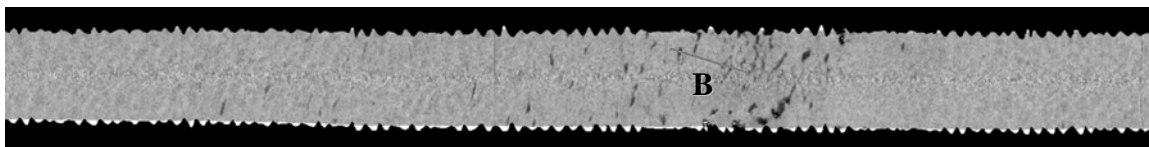
amplitudes of 10 – 15 cm may represent a response to along-shore currents (they are asymmetric with the steeper face on the western side – indicating net flow from east to west). They are also apparent from their slightly lower backscatter, overlaying the higher backscatter medium sand Figure 5(d).



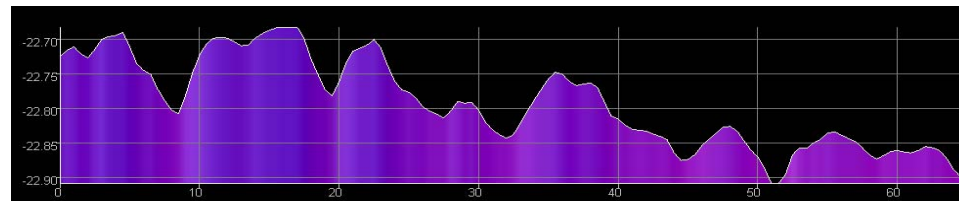
(a)



(b)



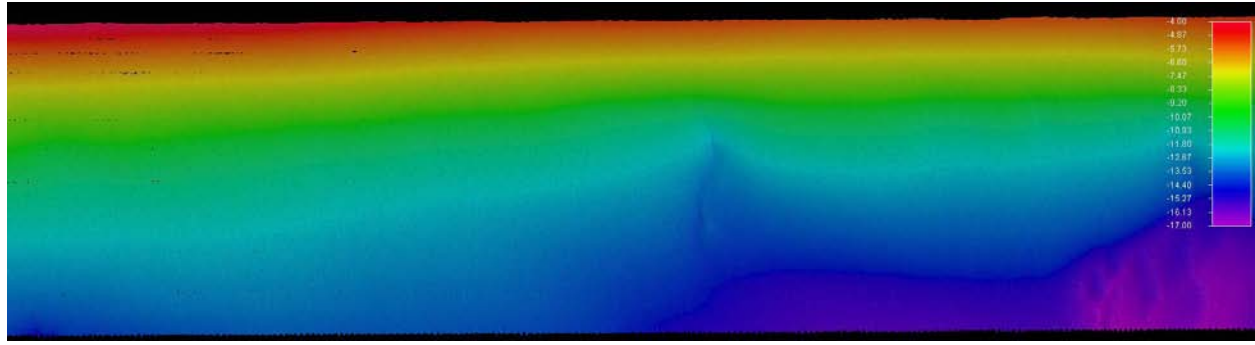
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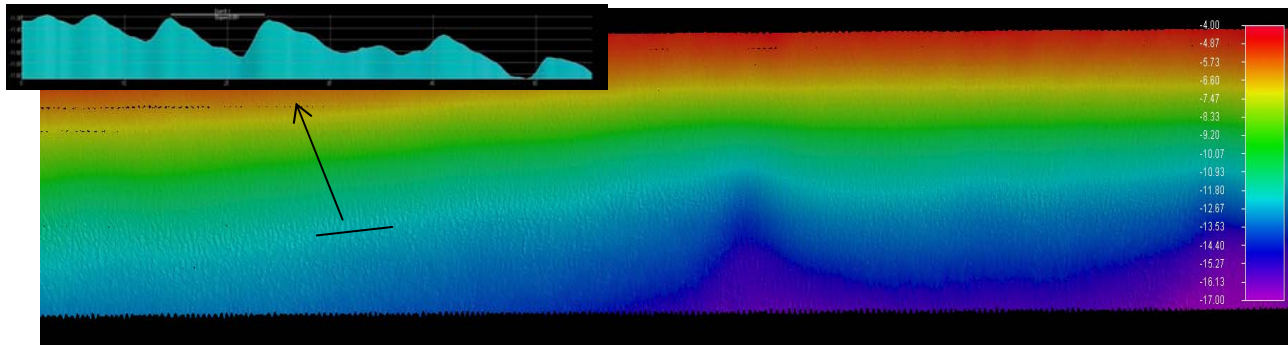
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**Figure 4. Reson 8125 bathymetry (a) and Simrad EM3002 backscatter (c) extracted from one of the NS Deep Water Lines in water depths between 20 and 23 m. Onshore direction is to the left. There are regions of very low backscatter (dark color) in some of the ripple troughs along profile B, indicating an accumulation of fine-grained sediment in the troughs. The cross-section profile A in (b) shows a slight asymmetry in ripple shape. Scale of cross-section profiles is 5 cm/div (vertically) and 10 m/div (horizontally).**

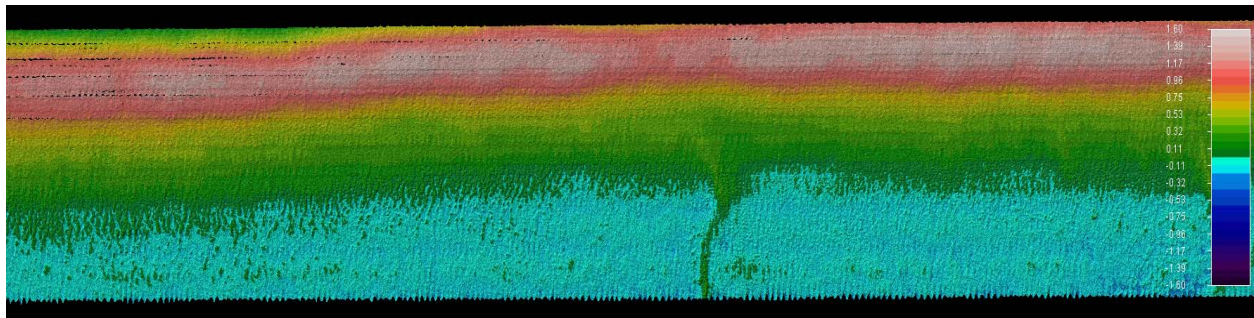




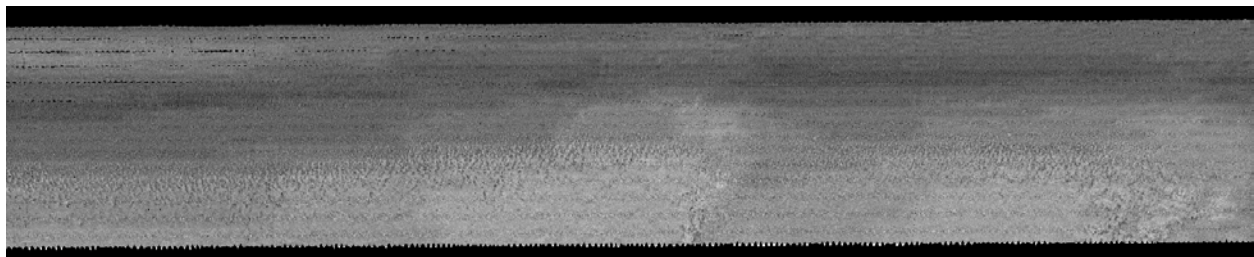
(a)



(b)



(c)



(d)

**Figure 5: Reson 8125 bathymetry (in meters) of the TOWER site during the (a) first and (b) second surveys; (c) bathymetric difference (second survey bathymetry relative to first survey bathymetry, in meters); and (d) Simrad EM3002 backscatter from the second survey with low backscatter (dark color) and high backscatter (light color).**

## **IMPACT/APPLICATIONS**

The initial survey has served as a base map for other investigations and a means of quantifying roughness spectra over a range of spatial scales (see Briggs et al., 2005). The single repeat survey has helped quantify the major change in seafloor bathymetry and sediment distribution after Hurricane Ivan (albeit six weeks after the storm) but the inability to mount a quick “event” response and subsequent surveys have greatly reduced the effectiveness of the mapping program.

## **TRANSITIONS**

Reson 8125 bathymetry of the TOWER and SAX04 sites has been transitioned to Dr. Todd Holland at the Naval Research Lab and Dr. Thomas Herbers from Scripps Institution of Oceanography. Profiles of bathymetric data along several NS and EW lines within the SAX04 site and along the NS direction in the SAX04 Deepwater Lines have been transitioned to Dr. Kevin Briggs at NRL to complete bottom roughness spectra.

## **RELATED PROJECTS**

Mine Burial and Uncertainty DRI's.

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Briggs, K.B., Lyons, A.P., Pouliquen, E., Mayer, L.A., and Richardson, M., 2005, Seafloor roughness, sediment grain size and temporal stability, in Papadakis, J.S. and Bjorno, L, eds. *Proceedings of the Intl. Conference on Underwater Acoustic Measurements: Technologies and Results*, Crete, Greece. ISBN: 960-88702-08